KERCH

Investigation of a
Highway Bridge

Civil Engineering

B. S.

1908

INVESTIGATION OF A HIGHWAY BRIDGE

BY

WALTER WASHINGTON KERCH

THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

PRESENTED, JUNE, 1908

UNIVERSITY OF ILLINOIS

June 1, 1908

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

WALTER WASHINGTON KERCH

ENTITLED INVESTIGATION OF A HIGHWAY BRIDGE

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Civil Engineering

C. W. Malcolm
Instructor in Charge.

APPROVED: Ira O. Baker.

HEAD OF DEPARTMENT OF Civil Engineering

PLATE I

1908
K45

INVESTIGATION OF A HIGHWAY BRIDGE

This thesis will have for its object the investigation of, and report upon a highway bridge. The nature of the report will be that required by highway commissioners of an engineer. The investigation will be according to Cooper's Specifications, Edition 1901.

The bridge in question is commonly known as the Woolen Mill Bridge, and spans the Vermillion River at Danville, Illinois. It was built by the Lafayette Engineering Company of Lafayette, Indiana, the metal all being from the Oliver works.

The structure is shown in Plates I and II. As seen in the outline diagram, the bridge consists of a river span and two viaduct approaches. The channel span is a Whipple or double Intersection deck truss bridge of ten panels, each panel being seventeen feet, three inches long. The west approach is built on a three per cent grade, and consists of nine trestle bents seventeen and a half feet apart, with built up metal sections for supports. The east approach consists of five deck Pratt trusses of four panels, each panel being seventeen feet, three inches long, together with four trestle bents the same as in the west approach. The roadway is seventeen feet wide, with two four-foot sidewalks, one on each side. The west abutment of the river span and the foundations of all the bents are of sandstone. The east abutment of the river span consists of two iron tubes filled with concrete, these tubes being braced by lateral stays and struts. The bridge was built to con-

nect the brickyard and the coal mines with the main part of town, consequently the loads supported are quite heavy.

The investigation will be made in three parts: Part I being a determination of the weights of the channel span; Part II will be the investigation of the several members of the channel span and Part III will be the investigation of the approaches.

PART I

ARTICLE 1.

Weight of Members of the Channel Span.

Ref. No.	Name of Piece	No. of Pieces	Cross Section	Weight Per Foot In Pounds	Length In Feet	Total Weight In Lbs.
1	END POSTS	4				
	Channels	8	9"	20.0	30.90	5160
	Cover Plates	4	16x1/4	13.6	30.90	1680
	Pin Plates	8	8x7/8	23.8	1.25	238
	Batten Plates	8	12x1/4	10.2	1.33	109
	Batten Plates	8	71/2x5/16	7.9	1.33	85
	Hinge Plates	4	16x5/16	17.0	2.33	158
	Pin Plates	8	8x3/8	10.2	0.66	66
	Angles	4	51/2x3x5/8	16.8	1.33	89
	Rivet Heads	556	3/4			75
2	TOP CHORD					
	Channels	8	9"	20.0	16.83	2700
	Channels	24	9"	20.0	17.05	8400
	Cover Plates	16	16x1/4	13.6	17.66	3780
	Splice Plates	28	8x3/8	10.2	1.66	475
	Splice Plates	14	16x1/4	13.6	1.58	302
	Pin Plates	8	8x5/8	17.0	1.50	204
	Batten Plates	32	12x7x1/4	10.2	1.17	382
	Batten Plates	64	12x5x1/4	4.2	1.17	318
3	LOWER CHORD					
	L_0L_1	8	4x3/4	10.2	20.33	1675
	L_2L_1	8	4x3/4	10.2	20.33	1675
	L_3L_2	8	4x1	13.6	20.33	2287
	L_4L_3	16	4x3/4	10.2	20.33	3314

Ref. No.	Name of Piece	No. of Piece	Cross Section	Weight Per Foot In Pounds	Length In Feet	Total Weight In Lbs.
	L_4L_5	16	4x1	13.6	20.83	4574
4	INTERMEDIATE POSTS					
	Channels	36	8"	16.2	25.58	14592
	Batten Plates	72	10x1/4	8.5	1.17	720
	Pin Plates	72	12x3/8	15.3	.66	720
	Batten Plates	72	8x1/4	6.8	1.17	575
	Lacing	1188	13/4x3/4	1.4	1.33	2370
	Rivet Heads	5184	1/2"			300
5	MAIN TIES					
	Eye Bars	8	31/2x5/8	7.4	35.00	2080
	Eye Bars	8	31/2x5/8	7.4	45.80	2735
	Eye Bars	8	31/2x3/4	6.3	45.20	2310
	Loop Bars	4	1 1/8x1 1/8	4.3	45.20	775
6	HIP VERTICAL					
	Loop Bar	4	3/4"	1.5	26.60	163
7	COUNTERS					
	Loop Bars	4	3/4"	1.5	44.40	268
	Loop Bars	4	1 1/2"	6.0	45.10	1082
8	FLOOR BEAMS					
	Web	20	18x1/4	15.3	8.50	4290
	Angle	20	3x2x1/4	4.1	22.20	1822
	Angle	20	3x2x1/4	4.1	22.00	1805
	Angle	80	2x2x1/4	2.8	1.00	224
	Fillers	80	2x1/4	1.7	.75	102
	Lacing	20	4x1/4	3.4	.84	73
	Lacing	40	4x1/4	3.4	1.33	181
	Lacing	20	3x3/8	3.5	3.00	210

Ref. No.	Name of Pieces	No. of Pieces	Cross Section	Weight Per Foot In Pounds	Length In Feet	Total Weight In Lbs.
	Lacing	20	61/2x1/4	5.3	1.00	111
	Rivet Heads	304	3/4"			40
9	BOTTOM LATERAL STRUTS					
	Channels	18	4"	6.2	14.30	1610
	Batten Plates	36	6x1/4	5.1	.83	152
	U Bars	32	61/2x3/8	8.3	2.68	400
	Lacing	468	1 1/4x3/16	0.8	1.00	374
10	TOP LATERALS					
	Lateral Rods	4	1 1/2"	6.0	23.00	525
	Lateral Rods	4	1 3/8"	5.0	23.00	465
	U Bars	32	6x1/2	10.2	1.00	326
	Lateral Rods	4	1 1/8	3.3	23.00	328
	Lateral Rods	4	1"	2.7	23.00	245
	Lateral Rods	4	3/4"	1.5	23.00	138
	Bolts	72	1"		25.00	55
	Sleeve	20	1"			62
11	BOTTOM LATERALS					
	Loop Bars	4	3/4"	1.5	23.8	145
	Loop Bars	16	1"	2.6	23.8	254
12	PORTALS					
	Loop Bars	4	1 7/8"	12.0	31.2	1500
	Bolts					105
	Turnbuckles	4	14"			25
12	CHORD PINS					
	Grips	21	3 1/2"	32.7	1.33	914
	Threads	42	2 7/8"	22.0	0.12	111
	Nuts					194

Ref. No.	Name of Piece	No. of Pieces	Cross Section	Weight Per Foot In Pounds	Length In Feet	Total Weight In Lbs.
17	PEDESTALS					
	Masonry Plate	4	26x3/4	66.3	2.50	662
	Base Plate	4	21x3/4	53.5	2.17	231
	Roller	18	2"	10.6	1.66	316
	Rods	4	1/2"	0.6	1.66	4
	Bars	4	1 1/2x1 1/2	1.2	2.00	10
	Angles	4	31/2x31/2x1/4	5.5	2.17	148
	Gusset Plate	4	1x1/2	20.4	1.33	111
	Angles	4	31/2x31/2x1/4	5.5	2.17	148
	Angles	4	31/2x31/2x3/8	8.5	2.17	231
	Plate	4	3 1/2x3/8	4.4	2.08	37
	Rivet Heads	232	3/4"			29
18	LUMBER BOLTS					
	Bolts	60	1/2	0.6	.83	40
19	SPIKES					
	Spikes	7266	20xd			808
20	HAND RAIL					
	Plate	20	4x3/16	2.5	17.30	882
	Flange	20	11/2x11/2	1.3	17.30	443
	Lacing	680	1x1/8	.4	3.50	1010
	Angles	80	11/2x11/2x3/16	1.8	4.00	576
	Angles	40	11/4x11/4x3/16	1.5	17.30	1040
	Brace	20	1"	2.6	5.00	260

ARTICLE 2

Weight of Lumber in Channel Span

Ref. No.	Name of Piece	No. of Pieces	Cross Section	Length In Ft.	Board Ft.	Weight Per Bd. In Lbs.	Total Wt. Lbs.
1	Flooring	173	12x21/2"	17.0	5190	4.5	23355
2	Felloe Gr.	20	6x4	17.3	692	4.5	3114
3	Walk	346	12x2	4.0	2768	3.0	8320
4	Joists	140	12x3	18.0	7560	3.0	22680

Weight of Wood = 57453 lbs.

Weight of Steel = 85510 lbs.

Total Weight of Bridge = 147174 lbs.

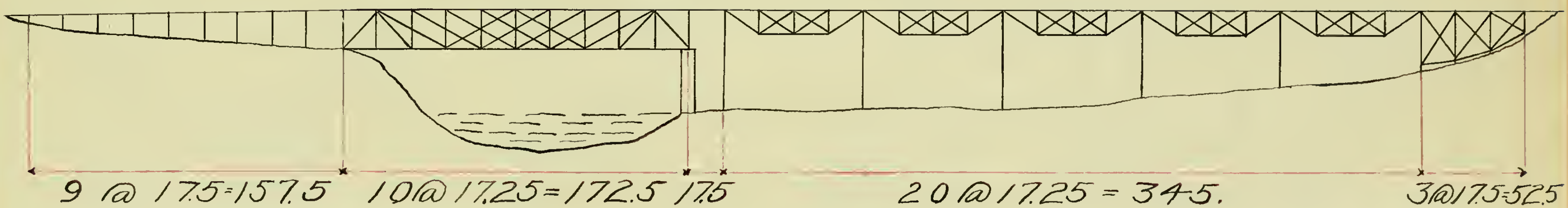


PLATE II

PART II

ARTICLE 3.

Determination of Panel Loads.

Total weight of bridge = 147174 lbs.

Weight per Truss = 147714 + 2 = 73587 lbs.

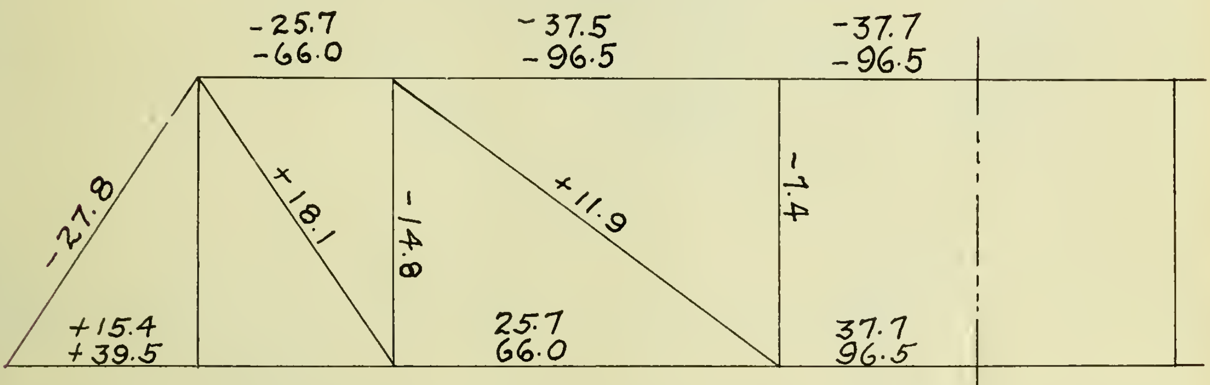
Dead Panel Load = 71481 = 71481 + 10 = 7360 lbs.

Live Panel Load = (17(100) + 8 (50)8.67 = 19000 lbs.

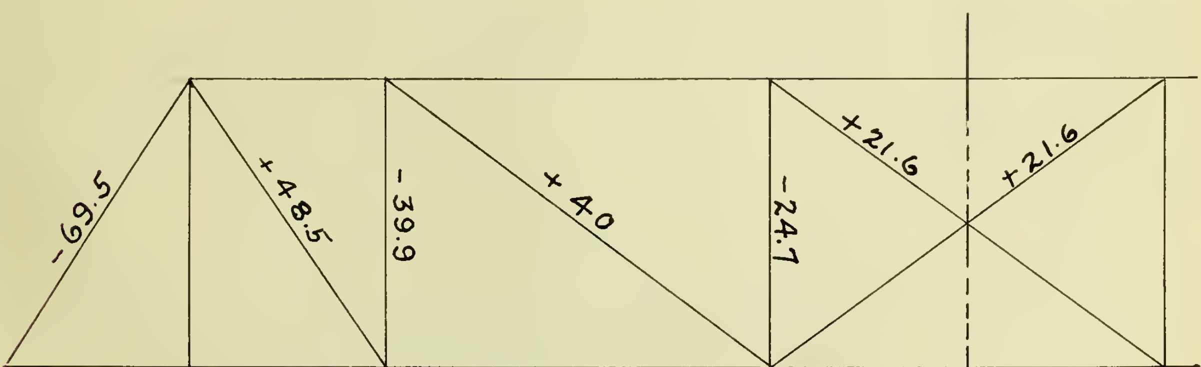
This live panel load is that recommended by the specifications for this class of bridge, and consists of 100 lbs. per square ft. of roadway, and of 50 lbs. per square ft. for the sidewalk space.

ARTICLE 4

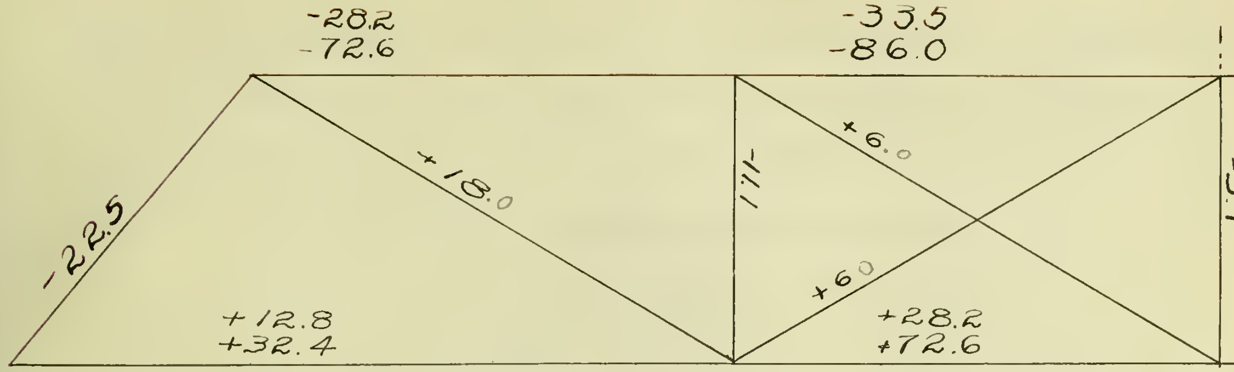
Computation of Maximum Stresses



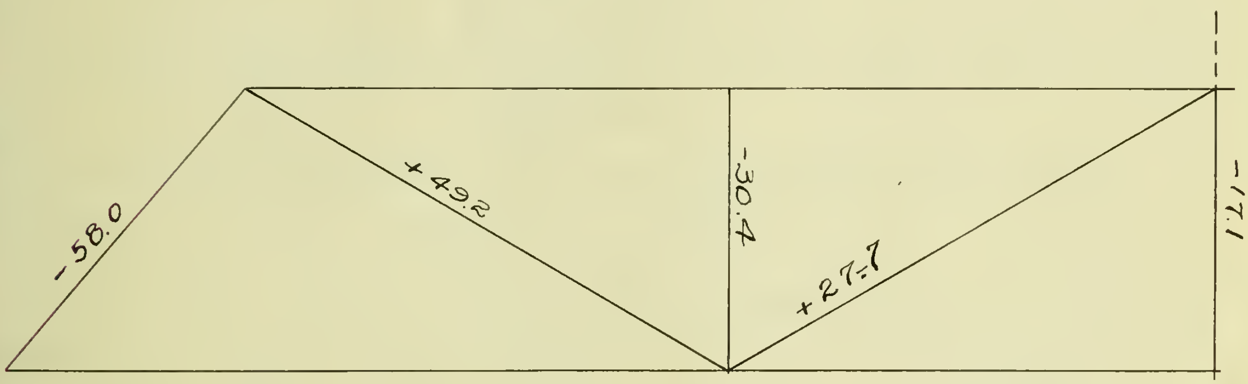
Dead and Live Load Chord Stresses and Dead Load Web Stresses



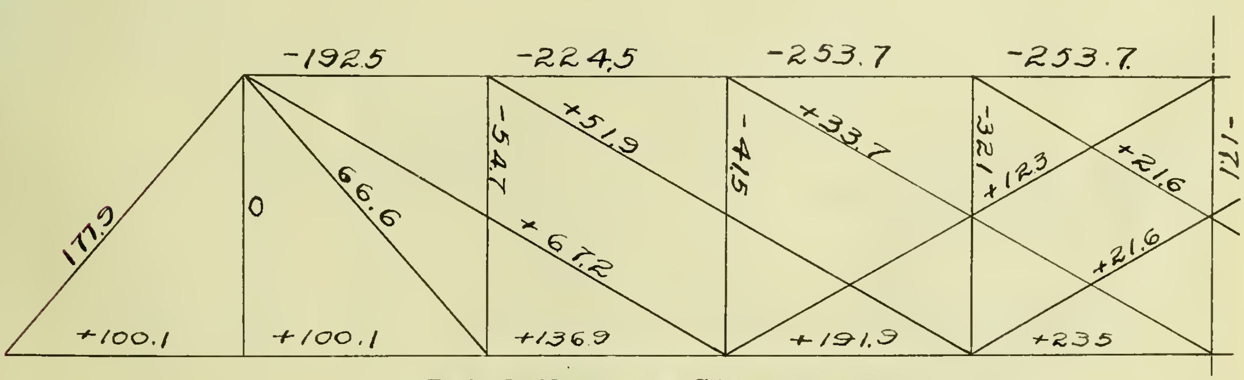
Live Load Web Stresses



Live and Dead Load Chord Stresses and live Load Web Stresses



Live Load Web Stresses

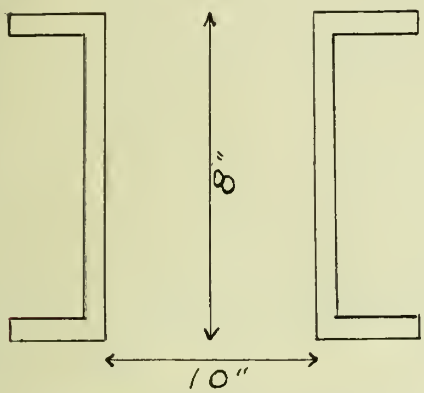


Total Maximum Stresses

ARTICLE 5.

INVESTIGATION OF INTERMEDIATE POSTS.

All the intermediate posts have the same section to add rigidity to the bridge. For this reason only the member L_2U_2 having the largest stress as shown in the diagram, will be investigated. Only the area of the channels are considered as effective.



Intermediate Posts

Maximum stress = 54700 lbs.

Allowable stress = 11000 ÷ (40) L/r

Actual area = 2(4.78) = 9.56 Sq. In.

Required area dead load = 14800 ÷ 17840 = 0.83 Sq.In.

Required area live load = 39900 ÷ 8920 = 4.50 Sq.In.

Total required area = 5.33 Sq.In.

Actual unit stress = 54700 ÷ 9.56 = 5720

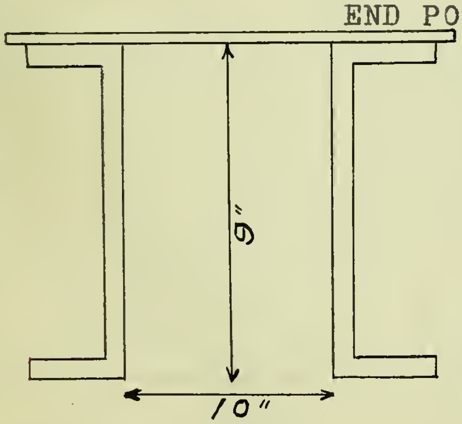
Allowable unit stress = 54700 ÷ 5.33 = 10250

Efficiency = 10250 ÷ 5720 = 179%

The intermediate posts are in first-class condition, showing that they are ample in design, and according to the specifications might well have been of a smaller section; as the value of L/r is well under 100.

ARTICLE 6.

END POSTS AND UPPER CHORD.



End Posts and Top Chord

Allowable unit stress, dead load = 22000 ÷ 80(L/r) = 12580

Allowable stress, live load = 6300

Actual area = 16(1/4) + 2(5.38) = 15.76

Required area dead load = 50400÷12580= 4 Sq.In.

Required area live load = 127500 ÷ 6300 = 20.2 Sq.In.

Total required area = 24.2 Sq.In.

Average allowable unit stress = 177400 ÷ 24.2 = 7330

Actual unit stress = 177400 ÷ 15.76 = 11300

Efficiency = 11300 ÷ 7330 = 65%

The stress due to wind is less than 25% of the live load stress, and the stress due to eccentricity and weight is less than 10% of the load stresses; therefore these may be neglected in determining the efficiency.

TOP CHORD

The stress in the member U_4U_5 is the maximum stress, and as the sections of the top chord are all the same this member only will be investigated.

Live load stress = 182500

Dead Load stress = 71200

Allowable stress live load = 12000 ÷ 55(L/r) = 8260

Dead load allowable stress = 24000 ÷ 110 (L/r) = 16500

Area required for dead load = 71200 ÷ 16500 = 4.3 Sq.In.

Area required for live load = 182500 ÷ 8260 = 22 Sq. In.

Actual average unit stress = 253700 ÷ 15.76 = 16000

Allowable average unit stress = 253700 ÷ 26.3 = 9600

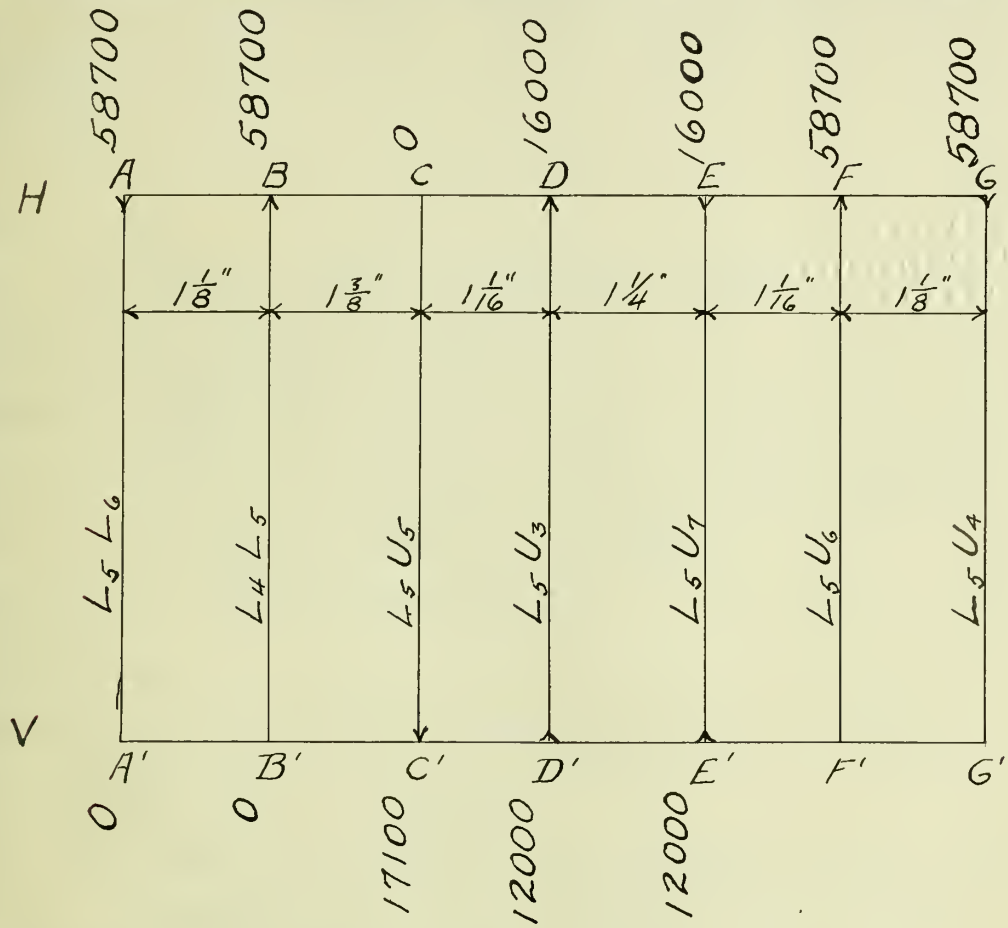
Efficiency = 9600 ÷ 16000 = 60%

The thickness of the cover plate on the top chord is 1/4 inch: the minimum thickness allowed by the specifications is 5/16 inch. Moreover, the distance between rivet lines is 13 3/4 inches and the maximum allowable distance is 40 times the thickness of the outside plate; thus the width of the cover plate that can be considered as effective area is only 10 inches. This will make the efficiency of the member still less, or 57%.

ARTICLE 7.

MOMENT ON PINS.

All the chord pins are three and one-half inches in diameter, except the one at the foot of the hip-vertical, that one being three inches. A careful investigation of the arrangement of the



members and their stresses showed the maximum bending moment to be in the pin at L_5. The diagram shows the packing on this pin. The maximum moment occurs when the stress in the lower chord is the greatest, and is 87400 In.lbs. The allowable unit stress in the pin is 20000 lbs. and for a three and one-half inch pin the total stress permissable = 84000 In.lbs. Efficiency = 84000 ÷ 87400 =96%.

ARTICLE 8

Tension Members.

For all tension members the allowable dead load stress = 25000 lbs., and the live load stress is 12500 lbs. The stress due to the weight of the member in every case was less than 10% of the load stresses, and for this reason has been neglected in determining the efficiency.

Lower Chord

Member L_0L_2

Dead load stress = 28200. Live load = 71900.

Actual area = 2(4)3/4 = 6 Sq.In.

Required area =(28000 ÷ 25000)+(71900 ÷ 12500)= 6.88 Sq.In.

Average allowable unit stress = 100100 ÷ 6.88 = 14500.

Actual unit stress 6 100100 ÷ 6 = 16700.

Efficiency = 14500 ÷ 16700 = 87%.

Member L_2L_3

Dead load stress = 38500. Live load stress = 98400.

Actual area = 2(4) = 8 Sq.In.

Total area required =(38500 ÷ 25000)+(98400 ÷ 12500)= 9.34 Sq.In.

Average allowable unit stress = 137000 ÷ 9.34 = 14700.

Actual unit stress = 137000 ÷ 8 = 17100.

Efficiency = 14700 ÷ 17100 = 86%.

Member L_3L_4

Dead load stress = 53900. Live load stress = 138000.

Actual area = 4(4)3/4 = 12 Sq.In.

Total area required = 53900 ÷ 25000 + 138000 ÷ 12500 = 13.56 Sq.In.

Average allowable unit stress = 191900 ÷ 13.56 = 14100.

Actual unit stress = 191900 ÷ 12 = 15900.

Efficiency = 14100 ÷ 15900 = 89%.

Member L_4L_5

Dead load stress = 65900. Live load stress = 169000.

Actual area = 4(4) = 16 Sq.In.

Required area = 65900 ÷ 25000 + 169000 ÷ 12500 = 16.17 Sq.In.

Average allowable unit stress = 235000 ÷ 16.17 = 14530.

Actual unit stress = 235000 ÷ 16 = 14670.

Efficiency = 14530 ÷ 14670 = 99%.

Main Members

Hip Vertical U L

There is no stress in this member, but the weight of the lower chord, so the 3/4 In. rod used is ample.

Member U_1L_2

Dead load stress = 18100. Live load stress = 48500.

Actual area = 2(3.5) (.625) = 4.38 Sq.In.

Required area = 18100 ÷ 25000 + 48500 ÷ 12500 = 4.6 Sq.In.

Actual unit stress = 66600 ÷ 4.38 = 15200.

Allowable unit stress = 66600 ÷ 4.6 = 14500.

Efficiency = 14500 ÷ 15200 = 96%.

Member U_1L_3

Dead load stress = 18000. Live load stress = 49200.

Actual area = 2(3.5) (.625) = 4.38 Sq.In.

Required area = 18000 ÷ 25000 + 49200 ÷ 12500 = 4.62 Sq.In.

Allowable unit stress = 67000 ÷ 4.62 = 14500.

Actual unit stress = 67000 ÷ 4.38 = 15200.

Efficiency = 14500 ÷ 15200 = 95%.

Member U_2L_4

Dead load stress = 11900. Live load stress = 40000.

Actual area = 2(2.5) (.75) = 3.75 Sq.In.

Required area = 11900 ÷ 25000 + 40000 ÷ 12500 = 3.68 Sq.In.

Allowable unit stress = 52000 ÷ 3.68 = 14100.

Actual unit stress = 52000 ÷ 3.75 = 13850.

Efficiency = 14100 ÷ 13850 = 102%.

Member U_3L_5

Dead load stress = 6000. Live load stress = 27700.

Actual area = 2(1.12) (1.12) = 2.52 Sq.In.

Allowable unit stress = 33700 ÷ 2.52 = 13500.

Actual unit stress = 33700 ÷ 2.49 = 13500.

Efficiency = 13500 ÷ 13400 = 101%.

Member U_4L_4

The dead load stress = 00. Live load stress = 21600.

Actual area = 1.76 Sq.In.

Required area = 21600 ÷ 12500 = 1.6 Sq.In.

Actual unit stress = 21600 ÷ 76 = 12275.

Allowable unit stress = 21600 ÷ 1.6 = 12500.

Efficiency = 12500 ÷ 12250 = 101%.

The tension members as a whole more nearly satisfy the requirements of the specifications, under the assumed loading, than any other part of the bridge. They are all in good shape and will be fit for service for years.

ARTICLE 9.

INVESTIGATION OF RIVETS

In only one case is the riveting faulty, for the least efficiency found, except in the case of the top chord splice, was greater for both shear and bearing than 100%. At the top chord splice there are three field rivets and three bolts in eacg channel and eight rivets in the cover plate. This makes the joints capable of transferring 35% of the total stress. The remainder

of the stress is supposed to be transferred directly, as the channels are spliced in the same vertical plane as the plates. This is contrary to the specifications and the joint shows the effect of over strain. The abutting members are battered and do not meet squarely. The nuts on the bolts are loose and the joint is very unsatisfactory. The distance between rivets should not be more than forty times the thickness of the cover-plate; or only this much can be considered as effective. The actual distance is 13 3/4 inches. The pitch of the rivets in the top chord is six inches and exceeds the allowed pitch by two inches.

ARTICLE 10.

INVESTIGATION OF JOISTS.

The joists are in very poor condition, are badly decayed, and in some cases have been replaced by new ones. The joists are of oak and are spaced two feet, center to center. The size of the joists is 3 by 12 inches.

Dead load = 1.89(2.5) (4.5) (17.25) = 368 lbs.

Live load = 1.89 (17.33)12 = 3280 lbs.

Total 3648 lbs.

M = 1/8 Wl = 3648(17.25)12/8 = 94900

M = SI/c

94900 = S (432)/6 = 1315 lbs.

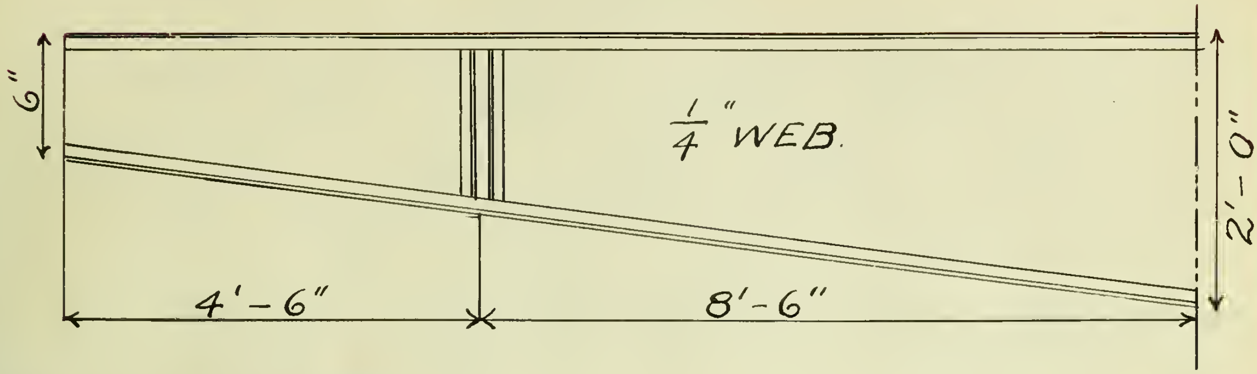
Allowable stress = 1000 lbs.

Efficiency = 1000 ÷ 1315 = 76%

A 16000-lb. traction engine, considering the load on four joists, gives an efficiency of 66%.

ARTICLE 11

FLOOR BEAMS.



Shear at the support:

Weight of the floor	1656 lbs.
Weight of the walk	535 lbs.
Weight of the handrail	510 lbs.
Live load on the walk	3466 lbs.
Live load on the roadway	14730 lbs.
Total	20887 lbs.

Required area of web at the support = 20887 ÷ 12500 = 1.66 Sq.In.

Actual area = 1/4 (12) = 3 sq.in.

Efficiency = 182%

Moment at the Center.

The maximum moment will come when the roadway alone is loaded.

Reaction at the joists = 3648 lbs.

Reaction at the support = 4(3648) = 14600 lbs.

Moment at the center = 1460098.5)12=(11+23+ 46+69+92)3650 =609500 Inch-pounds

Effective depth = 24 = 2(.49) = 23 inches

609500 ÷ 23 = 26500 = Stress in the flange

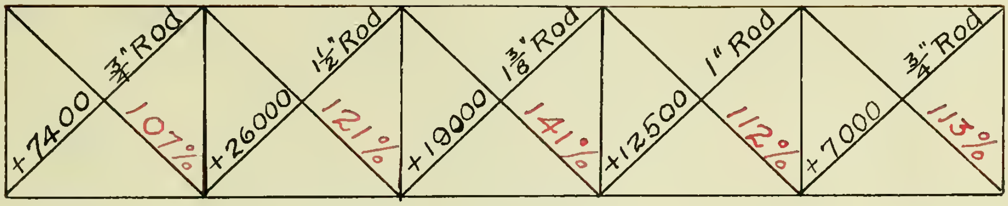
Allowable stress = 13000 lbs.

Required area = 26500 ÷ 13000 = 2.06 Sq.In.

Actual area = 2.38 Sq.In. Efficiency = 13000÷11100 = 117%

ARTICLE 12

TOP LATERALS



The assumed live load is 150 pounds per foot of truss, and the dead load is the same. The top lateral system consists of 10 panels, each 17.25 feet long.

Live panel load = 150(17.25) = 2600 lbs.

The dead panel load = 150(17.25) = 2600 lbs.

Allowable stress for all wind bracing = 18000 lbs.

Member U U

Stress = 26000 lbs.

Required area = 26000 ÷ 18000 = 1.45 Sq.In.

Actual area = 1.76 Sq.In.

Efficiency = 121%

Member U U

Stress = 19000 lbs.

Required area = 26000 ÷ 18000 = 1.05 Sq.In.

Actual area = 1.48 Sq.In.

Efficiency = 141%

Member U U

Stress = 12500 lbs.

Required area = 12500 ÷ 18000 =. 70 Sq.In.

Actual area = .78 Sq.In.

Efficiency = 112%

Member U U

Stress = 7000 lbs.

Required area = 7000 ÷ 18000 = 0.39 Sq.In.

Actual area = 0.44 Sq.In.

Efficiency = 113%

Member U U

Stress = 7000 lbs.

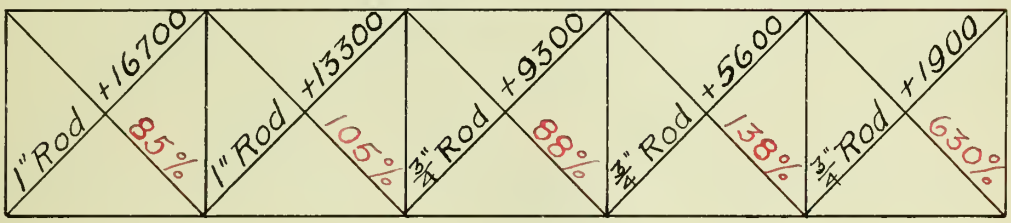
Required area = 7000 ÷ 18000 = .39 Sq.In.

Actual area = .44 Sq.In.

Efficiency = 111%

ARTICLE 13.

BOTTOM LATERALS.



The assumed load is 150 pounds per foot of truss, and acts as a dead load. The allowable stress is as before, 18000 pounds.

Member L'L

Stress = 16700 lbs.

The required area = 16700 ÷ 18000 = 0.93 Sq.In.

The actual area = 0.78 Sq.In.

Efficiency = 85%

Member L'L

Stress = 13300 lbs.

Actual area = 0.78 Sq.In.

Efficiency = 105%

Member L'L

Stress = 9300 lbs.

Required area = 9300 ÷ 18000 = .53 Sq.In.

Actual area = .44 Sq.In.

Efficiency = 88%

Member L'L

Stress = 9100

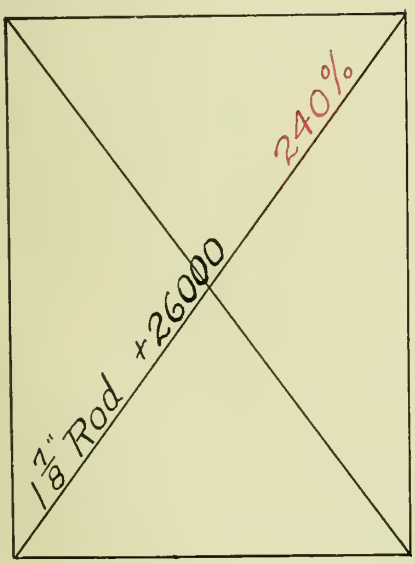
Allowable stress = 13000 ÷ 60(L/r) = 7250 lbs.

Required area = 9100 ÷ 7250 = 1.25 Sq.In.

Actual area = 2(1.84) = 3.28 Sq.In.

Efficiency = 260%

The remainder of the lower struts are of the same section, and have smaller stresses, so it is needless to investigate them further. An examination of the efficiencies of the lateral system shows they are satisfactory in most cases. There is one thing, however, that must be criticised, and that is the bending of the lateral rods and sway bracing at the connections. Some other method should be used.



ARTICLE 14.

PORTALS.

The form of the portal is shown in the sketch, together with the size of the members, the stresses, and the efficiencies.

Required area =26000÷18000=1.4 Sq.In.

Actual area = 5.5 Sq.In.

Efficiency = 240%

ARTICLE 15.

PEDESTAL AND ROLLER.

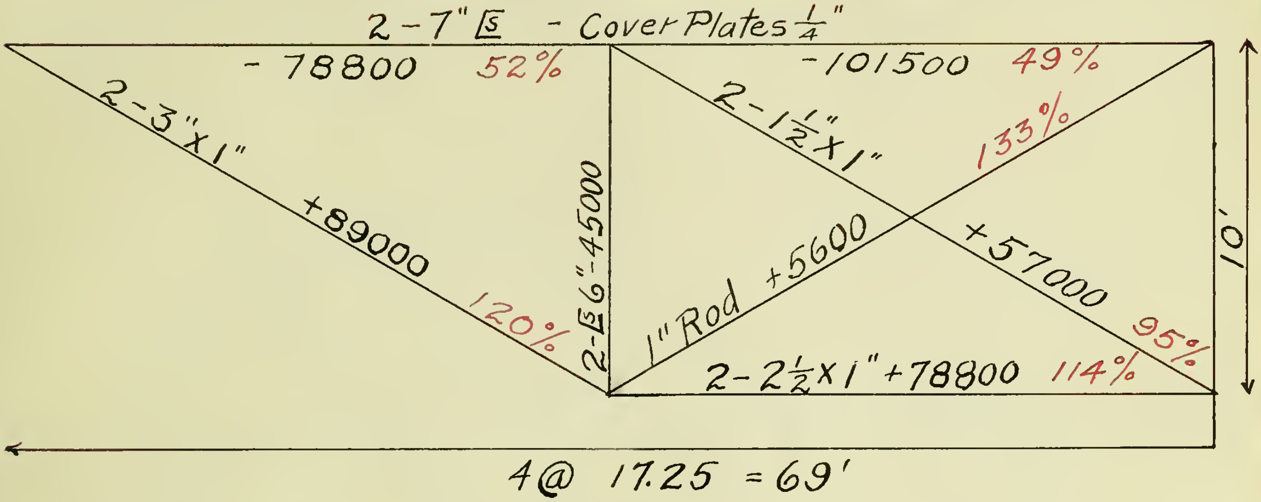
There are nine rollers under each end post. These rollers are two feet long and two inches in diameter. The efficiency of the rollers is 130%.

The bank has caved over the rollers and covers them to a depth of a foot or more, thus defeating the object of a movable end, as well as destroying the members thus covered. The angles of the roller-nest are not more than half their original thickness and will not last much longer unless some means are taken to preserve the remaining metal.

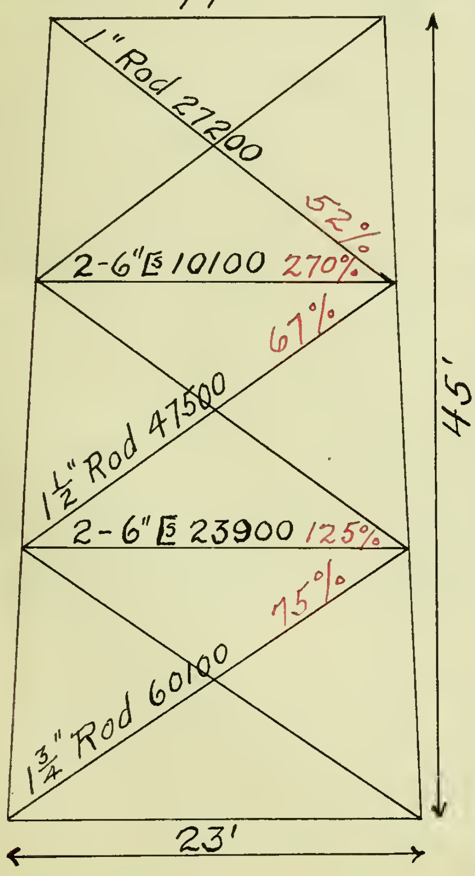
The specifications require two rows of rivets in the vertical leg of the pedestal angle. This requirement is not fulfilled in this bridge.

PART III

THE APPROACHES



The sketch shows the truss used. The dead panel load was found to be 6300 pounds, and the live panel load is the same as that for the river span. The size of the members, the stress, and their efficiencies are shown in the figure. The same general criticism ~~applies to the trusses~~ as does to the main span, as they are too light for the assumed loading.

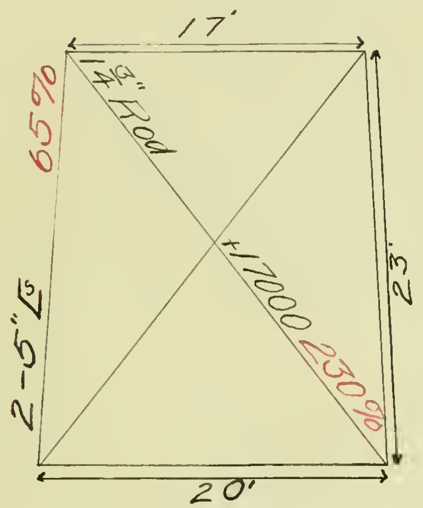


THE TRESTLE POSTS.

The stresses, sections, and the efficiencies of the members of one of the bents that support one of the Pratt trusses is shown in the Figure.

THE WEST APPROACH

The Figure shows the highest bent span of the west approach, its members, their stresses, and their efficiencies.



SUMMARY

The efficiencies of all the members investigated of the channel span are shown on the outline diagram of Plate III. An examination shows an average value of about 60%. The assumed load was for 100 lbs., so the safe load for the bridge, or one that would give an efficiency of 100%, is but 60 lbs. per square foot. The joists and the floor are in very bad condition, the pedestals are rusted half in two, and the bridge vibrates exceedingly under live load. For these reasons, I believe that the bridge should be replaced by a modern structure.

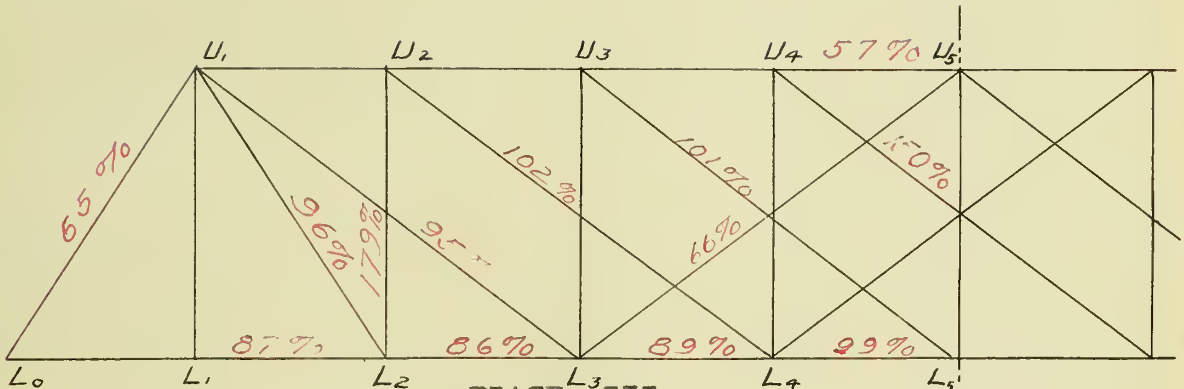


PLATE III

Efficiencies of Channel Span